Free Space Optics (FSO) and Light Fidelity (LiFi) Communications
A Modern Day Transitional Crossroads

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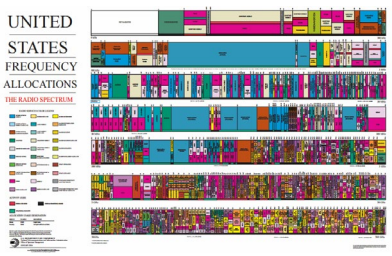
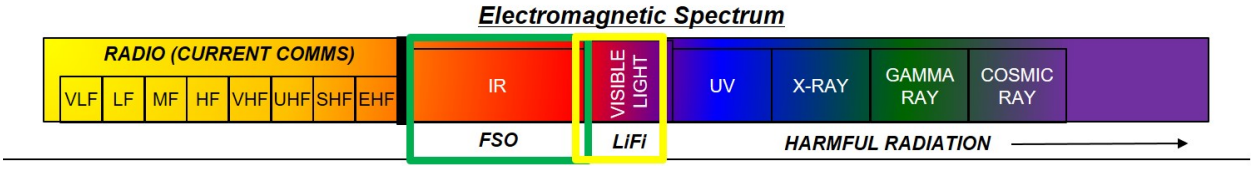
The United States Department of Defense and US Army are currently at a major transitional crossroads regarding strategic and tactical communications, and mission command. The US Army has not experienced the same type of major transition in over a century, when the warfighter transitioned from horses to trucks and semaphores to radios/phones on the battlefield. During any transitional crossroad, both technologies are utilized in tandem and add to the commander's toolbox to gain strategic, operational and tactical advantages. Transitional crossroads are not upgrades within current technologies, e.g. 4G to 5G communications, but entirely new technologies and ways of doing business, e.g. horses to trucks vice Model T to Model A. To appreciate the current transitional crossroad, it is critical to understand the Army has communicated entirely within the radio frequency (RF) portion of the electrometric spectrum (EMS) since the Spanish–American War in 1898. The RF spectrum, whether used for line-of-site or SATCOM, is highly detectible, congested, contested, and separately managed by each host nation.

US Army WWI Switchboard

Three major issues are problematic when operating entirely within the RF spectrum. First, a near-peer adversary will detect, attack through jamming or with direct fires, and attempt to intercept all RF communications used on the battlefield, leaving commanders with the inability to command and control their area of operations, ultimately putting Soldier's lives at risk. Second, host nations own and



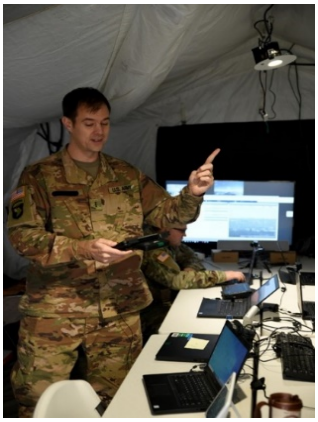
manage the RF spectrum, and US Forces must request permission to use any portion of the spectrum. Furthermore, host nations have the ability to deny access to US Forces for use and may sell any option without notice or coordination. To further aggravate the issue, US program developers often are not cognizant of the RF spectrum constraints overseas and wrongly assume US Forces can use portions available in the United States, at any power, especially if required in a crisis or operation. U.S. Army Europe and Africa (USAREUR-AF) are acutely aware that is this not the case and have dedicated enormous amounts of time and resources to host nation spectrum management and negotiation. Third, the RF portion of the spectrum is congested and has a finite amount of space, and 5G has not even started full implementation. A recent Politico article observed that "The Pentagon is likely to face security concerns in its overseas operations as its mid-band channels get crowded by Chinese-built devices"[1]



The solution to the RF associated problems, is to move outside the RF portion of the spectrum and into the low probability of detection (LPD), low probability of intrusion (LPI), and unmanaged portion of electrometric spectrum, namely the infrared (IR) and visible light (VL) portions. Two technologies that are currently available are Free Space Optics (FSO) and Light Fidelity (LiFi). Free Space Optics (FSO) brings a high-speed (Gb rate) spectrum diverse "wireless fiber" capability to the battlefield. FSO is a transport solution that uses an optical wireless broadband access technology utilizing the infrared

[1] Hendel, J., & Bender, B. (2020, Feb 2). The Pentagon Is Sitting on a Chunk of Valuable Airwaves. Why? Retrieved from politico.com: https://www.politico.com/news/agenda/2020/02/22/pentagon-airwaves-midband-106240

light spectrum. FSO is currently deployed with line-of-site and satellite communications. Light Fidelity (LiFi) utilizes either the visible light and/or the IR spectrum to create a wireless link with the user device and create a wireless communications network, offering a substantially similar user experience to other wireless communication technologies e.g. WiFi; however, proven much more secure. FSO and LiFi technologies answer all three of the serious issues associated with the RF portion of the spectrum. First, due to the low probability of detection, jamming, and intrusion, FSO and LiFi offer an extremely survivable form of communications when in direct conflict with a near-peer adversary. Dr. Paul Pellegrino of the Army Research Lab, stated in his final report on U.S. Army Europe's FSO/LiFi Demonstration that, "the objective of demonstrating a zero-RF footprint tactical operation center was significant. As the Army moves into contested environments alternative and complimentary forms of communication that maintain our networks is imperative. This demonstrably showed that a zero-RF emission tactical operation center is possible if optical communication links, both LiFi and FSO, are used in a tandem fashion to bridge data requirements and distances necessary." and "it is unclear that the Army has yet come to a full understanding of the potential impact that FSO communication systems can have on the next generation of Army network".[2] Secondly, FSO and LiFi reside outside managed spectrum therefore, no host nation authorization or coordination is required. The International Telecommunications Union (ITU) in a 2018 report concluded that, "light communications operations should be classified as license-exempt and not subject to exclusive licensing. This point of view was confirmed by a study



CW3 Czolada demonstrating LiFi

[2] Pellegrino, D. P. (2019). Free Space Optics (FSO) and Light Fidelity (LiFi) Communications. Combat Capabilities Development Command, U.S. Army Research Laboratory.

commissioned by the Radio communications Agency Netherlands."[3] Finally, the IR and VL portions of the spectrum are not congested and can be reused because light does not "penetrate" walls nor does LiFi signal emanation extend beyond a small cone of modulation. In other words, seeing the ambient light does not equate to receiving modulation. As a result, organizations are able to use the same portion of the optical spectrum throughout a building or room without interference and without competition of spectrum or bandwidth.

66th MI Soldier FSO Training

In October of 2019, under the direction of GEN Cavoli, USAREUR-AF CG, MG John H. Phillips, former USAREUR-AF CIO/G6, and CW5 Andrew Foreman USAREUR-AF G6 CTO, the United States Army Europe and Africa trail blazed the transitional crossroads for the Department of Defense by forging a new way to communicate and provide mission command. As a result 2nd Signal Brigade and 66th Military Intelligence Brigade became the first operational units, within the Department of Defense, to successfully deploy FSO and LiFi in tandem. Over the span of a 10-day exercise, USAREUR-AF demonstrated tactical command and control, transmitting a 16km link between 2 tactical operations centers (TOC) across farmlands, forests, the Rhine River, the city of Mainz, and the flight pattern of three airports in less than optimal weather conditions (rain, fog, wind), requiring no host nation permission or coordination, and provided 95% communications availability.

[3] (2018). Visible Light for Broadband Communications Report ITU-R SM.2422-0. ITU.

As a result of the highly successful FSO/LiFi demonstration, USAREUR-AF has continued to lead the way in the Department of Defense and with coalition partners regarding optical wireless communications. CW5 Foreman, working with industry, created a new use case at the tactical edge for LiFi. At the time of the demonstration, commercially available LiFi was manufactured within a single portion of the VL and/or IR spectrum. In order to provide added security and spectrum separation and diversity, three distinct VL and IR access points were designed, engineered and devolved. This new LiFi development resulted in a $4.2M investment of the pureLiFi Orion-XC™ LiFi devices at the tactical edge and limited use case for office LiFi. This effort is scheduled to deliver 400 tactical access points, 150 office access points, spanning three enclaves in support of Defender-Europe 21, making this the largest single purchase of LiFi to date.

pureLiFi Orion-XC™ Tactical Access Point

To further reduce the RF emission to the warfighter, U.S European Command and USAREUR-AF are the sponsor and lead service component, respectively, on an FSO proposal to the Office of the Undersecretary of Defense, Research and Engineering (OUSD-R&E). This Joint Capabilities Technical Demonstration (JCTD) proposal, Battlefield Secure Transmission Absent RF (BattleSTAR), intends to provide additional use cases for the deployment of optical wireless communications in support of joint operations. In an effort to support this proposal, USAREUR-AF is working closing with the Naval Research Lab (NRL) to purchase tactical and strategic FSO antennas over the next three years. Recognized as a leader and advocate for optical wireless communications, CW5 Foreman, was nominated by the Lead National Panel Member of Information Science Technology-NATO and selected by U.S. National Coordinator, Science and

Technology Organization-United States Delegation NATO as part of a six-member panel regarding FSO development to study development, propose use cases, ensure interoperability and recommend deployment opportunities.

Optical wireless communications, namely FSO and LiFi, is a new and developing means of communications for the military. Including optical wireless to the commander's toolbox is imperative to the survival of communications, command and control systems and, more importantly, Soldiers. Leadership within the Department of Defense are at a major transitional crossroads for communications and mission command systems and must make a critical decision. Start deploying LiFi and FSO and explore other optical wireless communications technologies or continue to subject the warfighter to increased emission by continuing to field highly detectable RF systems to the tactical edge, thus putting Soldiers and systems in dire straits.

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